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RADIATION INCIDENT OF FEBRUARY 1, 1956

Introduction

On February 1, 1956 at approximately 9:45 AM a homogeneous UO_2F_2 water moderated critical assembly was put on a prompt critical period, an event initiated by an over addition of fuel to the assembly. Although the automatic safety system operated, assuring termination of the burst, considerable fuel was displaced from the reactor. The number of fissions in the burst was estimated to be about 1.6×10^{17}. Since all building personnel were shielded by a minimum of 5 ft of concrete no serious exposures resulted. There was no significant property damage and recovery of all of the uranium is expected. Critical experiments were resumed in the working area on February 6 and the program which was interrupted will be continued as soon as some improvements in the equipment are made. The presently available information describing the incident and its consequences is given in this memorandum.

I. Description of the Equipment

The floor plan of the Oak Ridge critical experiments facility with the location of the critical assembly and the shielding noted is shown in Fig. 1.

The experiment in progress at the time of the incident was one in a series designed to evaluate certain reactor parameters by measuring stable reactor periods. Figure 2 is a diagram of the assembly. The reactor vessel, made of Type 2S aluminum, is a 30-in. diameter cylinder 6 ft high with walls and bottom 1/16 in. and 1/2 in. thick, respectively. A 2-in. diameter drain and feed tube is connected near the periphery of the bottom. The reactor was placed near the center of a steel tank, 9.5 ft in diameter by 9 ft high, which can be filled with water although none was present in this experiment.

The fuel storage system is connected through a 1/2 in. pipe to a manifold directly under the assembly. To this manifold are also connected the test cylinder and, through an air operated, spring loaded, normally open, 3-in. diaphragm valve, a safety reservoir consisting of a 5-ft length of 5-in. pipe. This valve is connected to the automatic safety system and, when opened, allows ~19 liters of solution to be drained from the reactor. From this reservoir the solution can be returned to the storage tank or it can be removed directly. Transfer of solution from storage to the test cylinder is effected by the application of air pressure to the storage vessel and flow is controlled by a remotely operated valve in the 1/2-in. pipe. With the control switch in the "feed" position this valve is open and the air pressure is applied; with the switch in the "drain" position the valve is also open but the air supply is turned off and the storage vessel is vented to the atmosphere.

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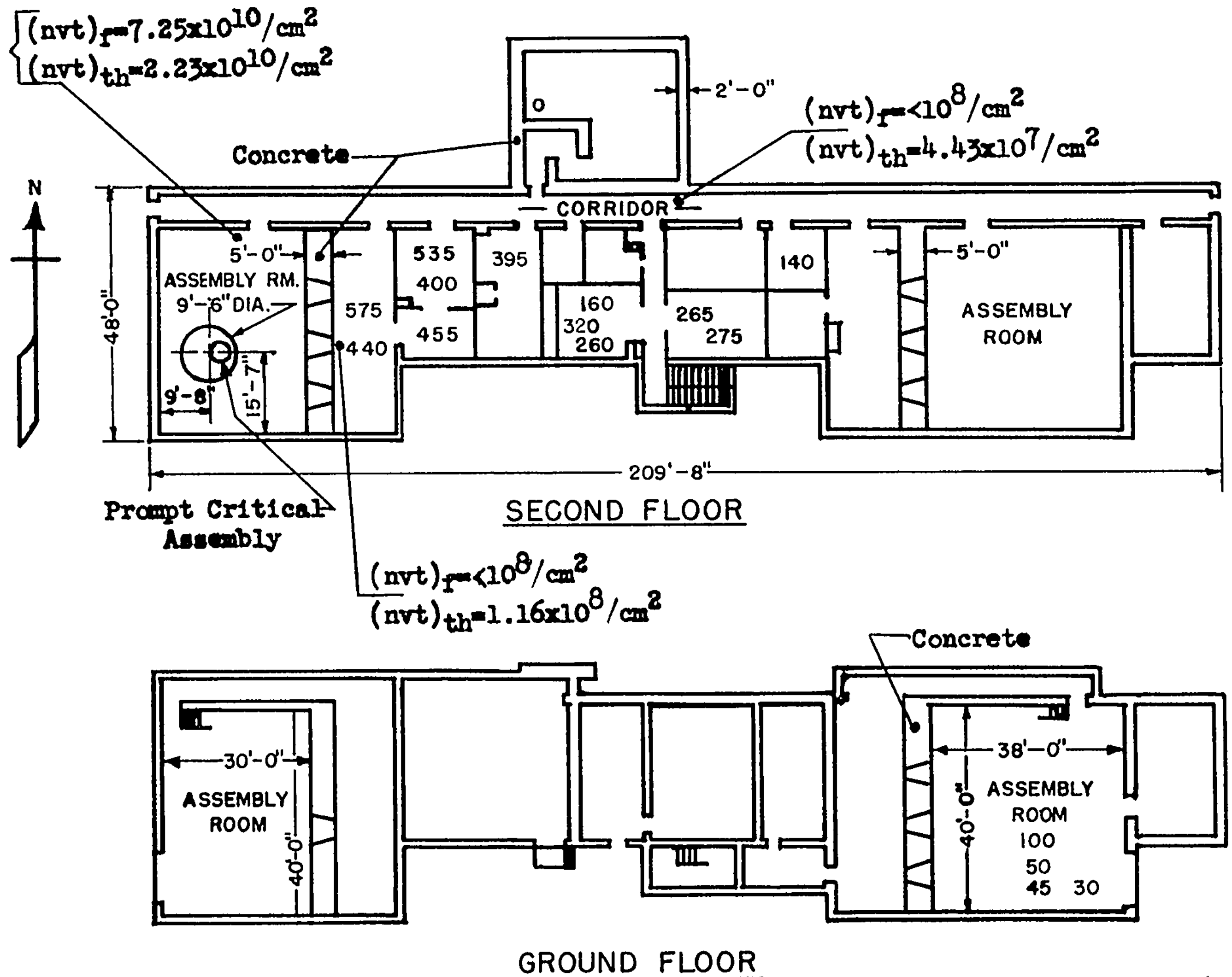

Notes: 1. Total exposures (mrem) received by individuals recorded at their positions.
2. Neutron exposures incurred by foils at three fixed points are shown.

Fig. 1. Critical Experiments Laboratory Floor Plan.

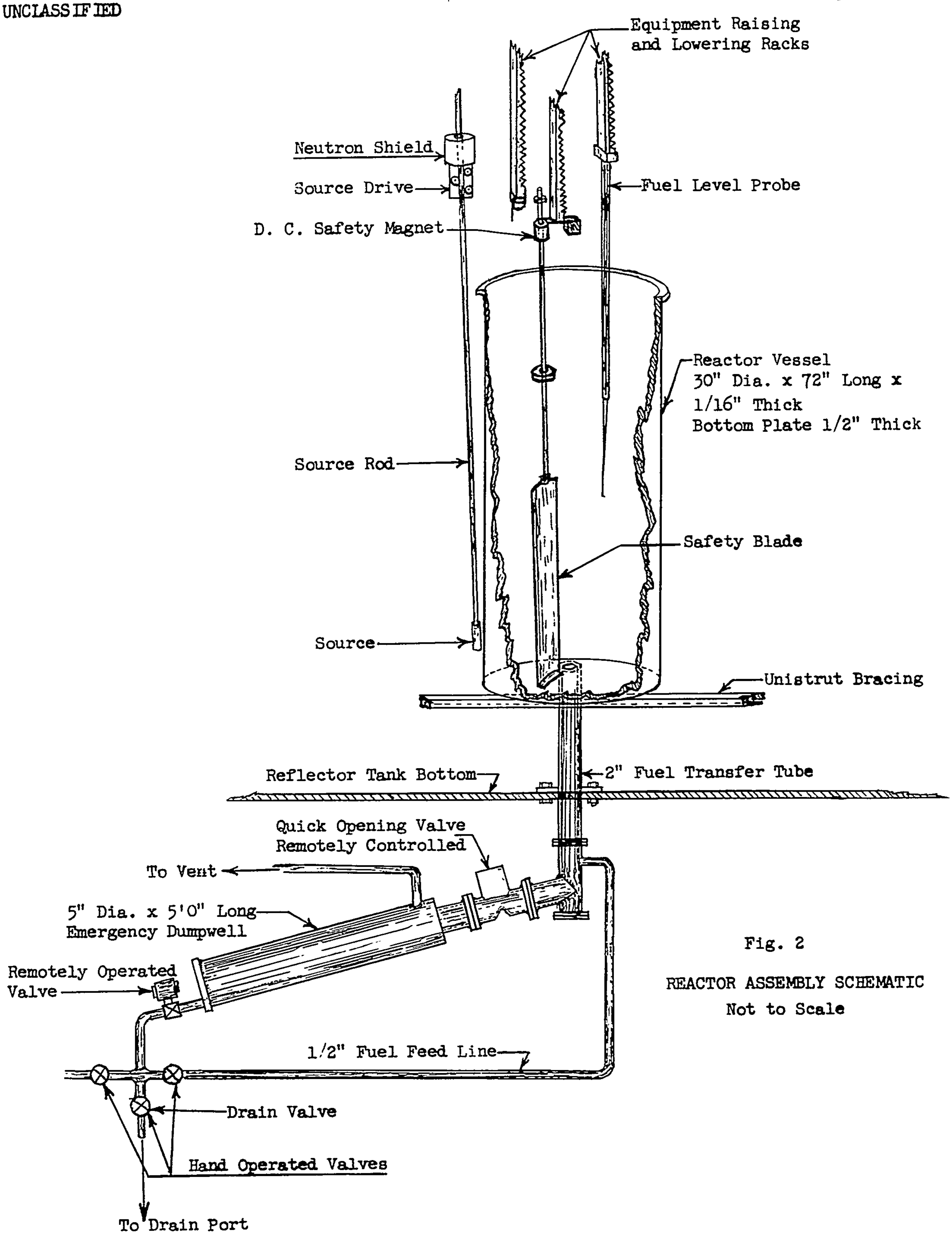

Fig. 2

REACTOR ASSEMBLY SCHEMATIC
Not to Scale

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The neutron source, which is used during an approach to critical, is positioned by a drive mechanism located above the assembly. The source when in use, is located at an outside surface of the reactor.

A super structure on top of the 9-ft cylindrical tank supports within the test cylinder a surface contact solution level indicator and, through a magnet, a 6-in. wide cadmium safety blade. These devices can be moved vertically by motor driven racks and pinions and their positions are indicated by selsyns. Other motors and drives are available for special uses.

II. Chronology of Events

The 30-in. diameter cylinder was being made critical by the successive addition of small increments of solution having a concentration of 0.47 gm U-235/cc and a specific gravity of 1.58. The U-235 concentration of the uranium was about 90%. After several additions to the reactor it was apparent from the control instruments that another addition would be needed to achieve a near critical system at the desired power level. The volume of the solution in the cylinder was 58.8 liters, about 100 cc less than the critical volume. The addition was made and the transient period decreased rapidly to approximately 30 seconds where it seemed to remain constant. Removal of the source was started at about this time and shortly afterward the fuel control switch was placed in the "drain" position. The period meter again indicated a rapid increase in reactivity. The safety devices were then actuated, about simultaneously, by both manual and instrument signal, the instrument trip point having been set at a ten-second period. Almost immediately a loud "boom" was heard which may have been the safety blade hitting the bottom of the reactor or it may have been due to the reaction. All recording instruments, including a logarithmic amplifier, were observed to be off scale showing that a power excursion had occurred so the area was evacuated.

A favorable wind velocity and the isolation of the laboratory made it possible to purge the test cell in which the accident occurred using ventilating fans installed during construction for that purpose. The small amounts of beta and gamma activity which fell out in other parts of the building were removed and, except for the test cell, occupancy was normal the morning of February 2. After the removal of the irradiated solution from the system to a shielded area on February 2 the background radiation was sufficiently low to allow unobstructed access to the test cell.

III. Cause of the Accident

The accident was initiated by an over addition of solution to the reactor. Later measurements showed that fuel will continue to be added to the reactor for several seconds after the control switch is placed in the "drain" position if insufficient time is allowed for the operating pressure to be vented. Extrapolation of some earlier measurements of excess reactivity as a function of solution height shows, however, that the rate at which solution can be

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added in this manner is insufficient to raise the reactivity from delayed to prompt critical in the time of the excursion. In fact, even the rate with full operating pressure is too low to account for the rapid rise. It is necessary, therefore, to consider other mechanisms by which the solution could have been made prompt critical.

It has been observed that the critical heights of cylindrical volumes of this solution, having diameters in the range considered here, are very insensitive to the diameter. (The critical height of a 30-in. cylinder is about 5 in., only 0.5 in. less than that of a 20-in. cylinder.) Any disturbance reducing the effective diameter of the solution would likely result in a concomitant increase in height to a value in excess of the critical height. Such a disturbance may have been caused by the insertion of the safety sheet. More definitive experiments are necessary to establish this mechanism.

IV. Observations and Results of Analyses

The total neutron and gamma ray exposures of persons in the building are shown in Fig. 2 at their locations at the time of the excursion. These results were obtained from film badges carried by the individuals and agree with the exposures shown by the neutron- and gamma-sensitive dosimeters carried by all persons. Also shown on Fig. 2 are the fast ($>$7 kev) and thermal ($<$0.5 ev) neutron doses (nvt) at three locations within the building. The results were obtained from the activities induced in plutonium, in gold, and in cadmium-covered gold foils.

Samples of the irradiated solution became available on February 2 for radiochemical analyses and for direct activity measurements. The following number of fissions which occurred per unit volume of the solution were derived from these analyses.

Isotope*	Fissions/ml
Ba-140	2.6×10^{12}
La-140	2.8
Sr-91	1.6
Ru-103	3.5
Cr-143	3.9
I-131	3.5

* The direct measurements of La-140 was done by Stuart Snyder of the Critical Experiments Group; we are indebted to S. A. Reynolds and E. I. Wyatt of the Analytical Chemistry Division for the other results.

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About 59 liters of solution were made critical. Assuming the total energy release to be 190 Mev per fission and using the more reliable Ba-140 and La-140 analyses, 1.6×10^{17} fissions occurred with an energy release of 3.0×10^{19} Mev or 4.8×10^{6} joules. The activity induced in a plutonium foil located 27 ft from the cylinder resulted from an exposure to 7.25×10^{10} fast neutrons/cm^2 which, in turn, would have been produced in the order of 10^{17} fissions. No temperature measurements were made in the solution. The volume of gas formed was about 12 liters.[1] Approximately 60 micrograms of U-235 were consumed. No light was observed by those who saw the displacement of the solution, perhaps a consequence of the liquid being near the bottom of a tall cylinder.

It is not possible at this time to estimate the excess reactivity or the duration of the excursion.

A basically similar event occurred on May 26, 1954[2] when about 2% excess reactivity was accidently added to a 10-in. diameter cylinder of solution about 40 cm high. At that time 10^{17} fissions occurred and the personnel exposures were about one half those incurred this time. Very little solution was forced out of the smaller cylinder although a flash of visible light was observed.

Grateful acknowledgement is made of the cooperation of Dr. K. Z. Morgan and other members of the Health Physics Division of ORNL in coping with this problem. The radiation exposures were determined by the Health Physics Division.

1. J. W. Boyle, "Reactor Science and Technology, Vol. 3, No. 1," TID-2008, p 32, (March 1953).
2. D. Callihan, "The Radiation Excursion of May 26, 1954, A Preliminary Report," CF 54-6-40, June 8, 1954.

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